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EXPERIENCE WITH CAPTURE CAVITY II*

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Abstract

Valuable experience in operating and maintaining superconducting RF cavities in a horizontal test module has been gained with Capture Cavity II. We report on all facets of our experience to date.

INTRODUCTION

Capture Cavity II (CCII) is a 9-cell high gradient TESLA Superconducting cavity intended to upgrade the existing Fermilab Photoinjector electron beam energy from 15MeV to 40Mev. DESY provided the cavity which was then shipped under vacuum to FNAL. After extensive preparation and conditioning, the cavity performed to 33MV/m at FNAL at the ILC test stand located in the Meson Detector Building. First results were presented at the LINAC 2006 conference [1]. These results include 4.5K and 1.8K operation with a 1.4 ms RF pulse and under LLRF control. This current work reports on performance and activities since then.

CAVITY PERFORMANCE

Since first results were reported, CCII has undergone three modes of operation: operation and studies with gradients as high as 30 MV/m, an extended shutdown period, and reduced gradient performance. Each are summarized below.

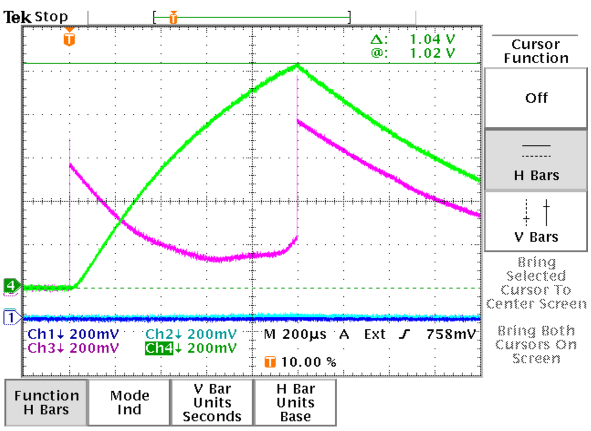

Figure 1: Operation of CCII at nominal 30 MV/m gradient. Green trace is Transmitted power, Magenta trace is Reflected power. Horizontal marker indicates 30 MV/m.

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High Gradient Operation

As was reported previously [1], CCII was able to achieve gradients as high as 31.3 MV/m, but not without difficulty. Mechanical vibrations at ~18 and ~180 Hz were identified as a probable source of unstable operation which prevented the Low Level RF system from regulating the cavity. During an extended shutdown period described below, these vibrations were largely eliminated. Details are provided elsewhere at this conference [2].

With it possible to operate in closed loop mode, much time has been expended commissioning and upgrading the LLRF system [3].

Recently, new mechanical vibrations at 21 and 42 Hz have been observed and are correlated with operating the cryogenic system operating at 1.8K. The amplitude of the vibrations is inversely proportional to the single-phase helium supply pressure. Investigation into this continues.

Other studies include investigation of Lorentz force de-tuning and compensation of same [4].

Shutdown

From September through November, 2006 there was an extended maintenance period for CCII. This was the first opportunity to access the interior of the cryostat since operation first commenced at Fermilab. The chief tasks were:

- Replace a failed slow tuner motor
- Install a support structure to reduce mechanical vibrations
- Install thermometry on the Higher Order Mode coupler bodies
- Address constraints on the Main Input Coupler

When it became impossible to adjust the resonant frequency by driving the slow tuner, it was suspected that the original Sanyo motor was shorted. Upon inspection, it was discovered that the motor leads had been inadvertently shorted together within the cryostat. Nevertheless, a Phytron motor specifically designed for operation in cryogenic and UHV conditions was installed. Its performance was verified prior to closing up the cryostat. In tandem, a motor controller with integrated motor over-temperature protection was designed and installed.

Finite Element Analysis of the vibrations, determined that the beam pipe/bellows assemblies joining the cavity (cold) to the cryostat (warm) did not have sufficient mechanical support. 2 sets of unconstrained bellows were allowed to excite cavity mechanical resonances. Radial constraints fabricated of G-10 were installed which have significantly damped these vibrations. Figure 2 shows a comparison of vibration amplitude before and after the shutdown to install the constraints.

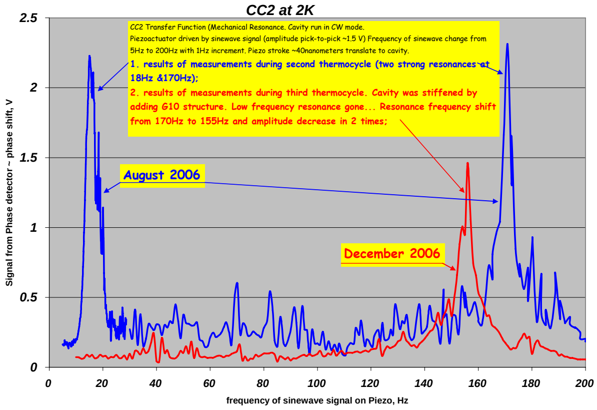

Figure 2: Result of addition vibration damping supports on CCII ends. The blue trace shows amplitude and frequency as found, while the red trace is that following installation of a new support structure

In order to monitor possible heating of the HOM's during operation, platinum resistors were mounted on the HOM body at each end of the cavity. Each HOM has three strategically placed sensors. Remote readout and archiving through the resident controls system is possible.

Reduced Gradient

In early March, 2007 during a period of piezo measurements, the maximum achievable gradient took an abrupt drop with CCII unable to hold a gradient above 16 MV/m at its fundamental frequency. Quenches were accompanied by significant electron emission and vacuum activity. Curiously, quenches invariably occur late in the RF cycle as figures 3, 4, and 5 indicate.

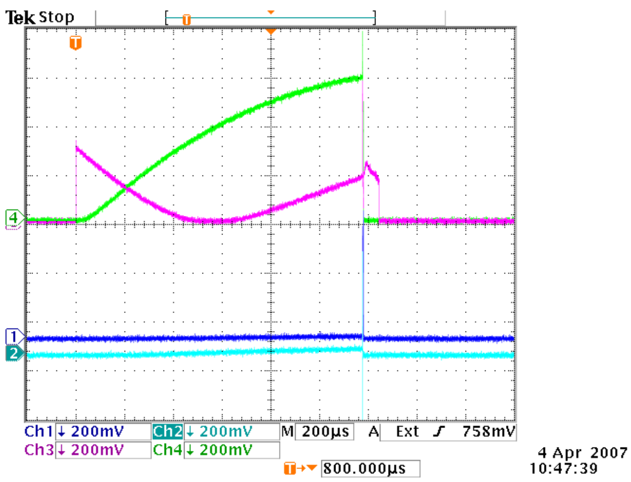

Figure 3: CCII Quench at low (16 MV/m) gradient. Green – transmitted power, Magenta – reflected power, Cyan – rectified Downstream HOM power, Blue – rectified Upstream HOM power

Extensive mechanical investigation including vacuum leak checking of the cryostat and thermal cycling to room temperature reveal no clear root cause. Operating at other resonances, such as the 7π/9 and 8π/9 modes did allow the cavity to achieve gradients of 25 and 30 MV/m respectively. Another round of input coupler conditioning was done with no change in operation.

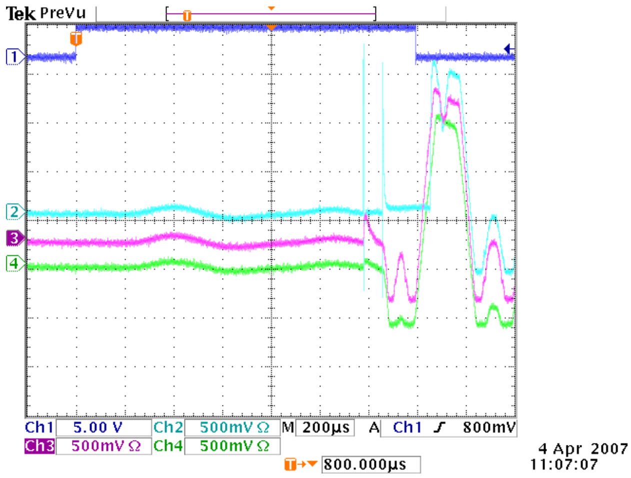

Figure 4: CCII Quench at low (16 MV/m) gradient. Green – 300K e- pickup, Magenta – 80K e- pickup, Cyan – 4K e- pickup, Blue – RF gate (trigger)

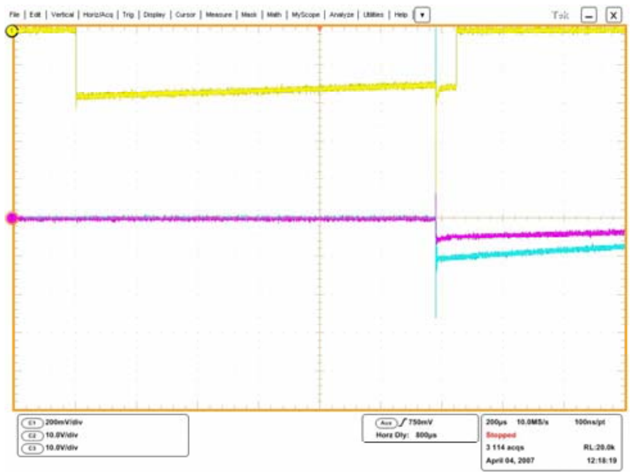

Figure 4: CCII Quench at low (16 MV/m) gradient. Yellow – Forward power, Magenta – Downstream Faraday Cup, Cyan – Upstream Faraday Cup

Following a second thermal cycle, normal operations were able to resume. This was short-lived, however, as in early June, following a 'spontaneous' change in the cavity Q_{loaded} and an adjustment to the coupling to compensate, CCII reverted to its low gradient output. Behavior now is virtually identical to that observed previously.

Historically, the input coupler was difficult to condition and it deserves mention as a prime suspect. Investigation continues.

Other Activities

In parallel with operation of CCII and LLRF commissioning, other upgrades have been carried out. The interlock system, which will inhibit the RF output if off-normal conditions such as excessive vacuum activity, arcing in the coupler, or excessive electron emission, is sensed, has been given an extensive upgrade in anticipation of parallel operations with the adjacent ILC Horizontal Test Stand (HTS) now being commissioned. High Level RF changes have been made also in anticipation of HTS operation in the near future.

SUMMARY

CCII is proving to be a rich proving ground for Fermilab personnel in gaining experience operating a Superconducting RF Cavity system. In recent months, three distinct phases: operation at 30 MV/m, shutdown, and now two periods where the gradient is barely half that of nominal have been experienced. When operating normally, progress has been made in bringing the Low Level RF system to maturity and in developing expertise in the field of Lorentz Force detuning compensation.

Bouts with low gradient have struck twice. Investigation continues to understand the source and resolve this issue.

CCII will be relocated to the ILC test facility at the Fermilab's NML building once the infrastructure is in place to support its operation.

AKNOWLEDGEMENTS

The work carried out to date and progress made as presented in this paper is the result of many individual and collaborative contributions. The number of involved staff persons from the Accelerator, Computing, and Technical Divisions at Fermilab is growing as is the SCRF expertise of all involved. Technical advice from our colleagues at DESY, most noteworthy of whom is Wolf-Dietrich Möller, is greatly appreciated.

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